Growth Promoting Antibiotics in Food Animal Production: An Economic Analysis

Jay P. Graham, MBA[a]
John J. Boland, PhD[b]
Ellen Silbergeld, PhD[a]

SYNOPSIS

Objective. Considerable controversy persists regarding the use of human antibiotics to promote growth in animals raised for food. The authors examined the economic effect of removing antibiotics used for growth promotion in commercial broiler chickens.

Methods. The authors utilized data published by the Perdue company, the fourth largest poultry producer in the United States, in which a non-randomized controlled trial of growth-promoting antibiotic (GPA) use was conducted with seven million broiler chickens to evaluate the impact of removing GPAs on production.

Results. Positive production changes were associated with GPA use, but were insufficient to offset the cost of the antibiotics. The net effect of using GPAs was a lost value of $0.0093 per chicken (about 0.45% of total cost). Based upon these data, the authors found no basis for the claim that the use of GPAs lowers the cost of production. Note that this study does not include veterinary cost changes or changes in performance variability associated with the removal of GPAs.

Conclusions. This economic analysis is the first study to the authors' knowledge utilizing large-scale empirical data collected by U.S. industry, in which it is demonstrated that the use of GPAs in poultry production is associated with economic losses to the producers. These data are of considerable importance in the ongoing national debate concerning the continued use of antibiotics for growth promotion of food animals. Based on the industry study and the resulting economic impact, the use of GPAs in U.S. poultry production should be reconsidered.

[a]Department of Environmental Health Sciences, Division of Environmental Health Engineering, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD

[b]The Johns Hopkins University, Baltimore, MD

Address correspondence to: Jay P. Graham, MBA, MPH, Doctoral Candidate, Johns Hopkins Bloomberg School of Public Health, Department of Environmental Health Sciences, Division of Environmental Health Engineering, 615 N. Wolfe St., Baltimore, MD 21205; tel. 410-467-4286; fax 410-955-9334; e-mail <jgraham@jhsph.edu>.

There is considerable controversy over the use of human antibiotics to promote growth in animals raised for food.[1,2] The World Health Organization, the American Medical Association, and the American Public Health Association have urged a ban on growth-promoting antibiotics (GPAs), arguing that their use leads to increased antibiotic-resistant infections in humans. In contrast, commercial interests have argued that their removal will have a significant impact on the cost of production and is unlikely to affect the risk to humans from antibiotic-resistant infections.[3,4]

The use of antibiotics to enhance growth and feed efficiency and reduce mortality in broiler production was introduced without rigorous testing as to efficacy some 50 years ago.[5,6,7] Improvement in growth due to antibiotics was first described in the mid 1940s, and within five years the addition of GPAs became common practice.[8] During this initial period, it was hypothesized that the antibiotic growth effect was due to the reduction of pathogenic bacteria in the intestinal tract of chicks.[9] In one test of this hypothesis, researchers raised chickens in a hygienic environment and demonstrated that there was little difference in growth between chicks fed a diet with GPAs vs. chicks receiving a diet without GPAs.[6,9] Currently, several mechanisms of action are attributed to antibiotics, but no clear understanding has been achieved.[10–17]

Few published studies since this time have provided evidence for a significant effect of GPAs on growth rates, feed conversion efficiency, or quality of the flock, which are the characteristics of importance in the economics of poultry production. It is appropriate to reconsider the premises for GPAs, since over the past 50 years many major changes in poultry production have been introduced, including selective breeding, controlled environments (lighting, temperature, and humidity), and supplementation of feeds with vitamins and minerals.[18] Taken together, broiler production changed dramatically from 1955 to 1995: the average market weight of broilers has increased nearly 50%, and the time needed for broilers to reach market weight and the amount of feed required to produce one pound of broiler meat have both declined approximately 35%.[18] It is asserted by industry researchers that GPAs are an essential component in maintaining these increases in productivity, which have contributed to the decreased cost of chicken products for consumers.[3]

There is increasing public health concern, however, over the use of antibiotics for growth promotion in food animal production related to the contribution of this use to increasing rates of antibiotic resistance.[2] Studies have shown that the use of GPAs contributes to contamination of flocks and food products by antibiotic resistant pathogens, including *Campylobacter*, *Salmonella*, *Enterococcus* and *Escherichia coli* and thereby to increased risks of human infections by these and other resistant pathogens.[19,20] The European Union, in 1999, banned the use of most antibiotics for growth promotion to preserve the effectiveness of important human drugs.[4] The U.S. has not adopted this broad policy, but in 2004 the U.S. Food and Drug Administration banned enrofloxacin (a fluoroquinolone applied for therapeutic uses, not growth promotion) in food animals on the grounds that its use contributed to fluoroquinolone resistance in human pathogens.

In current poultry production, feed formulations are adjusted throughout the lifespan to meet specific growth needs. The Figure lists the antimicrobial agents approved in broiler production; all of the antimicrobials are marketed over the counter in the U.S.[10]

The use of GPAs is loosely defined as antibiotics provided to healthy animals at concentrations below 200 grams per ton of feed for more than 14 days.[21] This is distinguished from therapeutic and prophylactic antibiotic use, which is delivered at higher doses and generally administered in water. These small amounts result in subtherapeutic doses, a condition which is particularly conducive to selection for resistance in bacteria. Estimates of the amounts of GPAs used in U.S. animal production range from 3.1 million pounds to approximately 25 million pounds annually (i.e., range from 13% to 70% of all antibiotic use).[22,23] This high variability in estimates stems from the failure of current regulations to require public reporting of actual use and the increasingly contentious nature of the debate, highlighted by a recent article in a trade magazine recommending that animal producers not reveal information to external sources on the use of antibiotics.[24]

In the policy debate over GPAs, there has been relatively little examination of the industry claims that a ban on GPA use would result in detrimental effects on production costs and industry practices.[1] For example, in a recent report on antibiotic use in agriculture, the National Research Council accepted an unsubstantiated industry estimate and concluded that a 1.76% increase in poultry production costs would arise from the removal of GPAs, resulting in an increased cost to consumers of $2.20 per capita per year.[25]

If true, these costs merit consideration in terms of policy making because of their potential impacts on the U.S. poultry industry and on consumers. In this analysis, we utilized a recent industry study of the impacts of GPAs on poultry production. Most estimates to date have been based on data collected prior to the 1980s and no large empirical studies have ever been

Figure. Antimicrobial agents approved for use in broiler production[a]

Coccidiostats (antiprotozoal drugs)

Sulfonamides	*Ionophores*	*Others*
Sulfachloropyrazine	Lasalocid	Amprolium
Sulfamethazine	Maduramycin	Arsanilate (arsenical)
Sulfadimethoxine	Monensin	Buquinolate
Sulfamyxin	Narasin	Clopindol
Sulfanitran	Salinomycin	Dequinate
Sulfaquinoxaline		Nequinate
		Robenidine
		Zoalene

Antibiotics and arsenicals

Aminoglycosides (streptomycin, neomycin, gentamycin)
Aminocyclitols (spectinomycin[b])
B-Lactams (penicillins[b])
Decapeptides (bacitracin[b])
Fluoroquinolones (enrofloxacin, sarafloxacin)
Lincosamides (lincomycin)
Macrolides (erythromycin, tylosin[b])
Tetracyclines (chlortetracycline,[b] oxytetracycline, tetracycline)
Streptogramins (virginiamycin[b])
Bambermycin[b]
Novobiocin
Oleandomycin[b]
Arsenicals (roxarsone,[b,c], arsanilic acid[b])

[a]Adapted from NRC, 1999 and USDA, 2001.

[b]Labeled as growth promoter

[c]The most commonly used arsenical compound in poultry feed.

SOURCE: Hancock TC, Miller CV, Denver JM, Riedel GF. Fate and transport of arsenical fee amendments in Chesapeake Bay watersheds. Society of Environmental Toxicology and Chemistry 21st Annual Meeting; 2000 Nov 12–16; Nashville, TN.

performed in the U.S. to measure productivity changes. Early studies, conducted from 1950 to 1960, showed mean increases in body weight of 8.5%–8.8% using penicillin and 10.2%–12.3% using tetracyclines.[26] From 1968 to 1980, median body weight increases were found to be 11% for penicillin, 8%–10% for the tetracyclines, and 4%–7% for the "new" antibiotics.[27] It should be noted that most of these studies were conducted prior to many innovations and advances in poultry science, including selective breeding and changes in animal husbandry and feed formulas.

Studies of GPAs in broiler production have examined weight gain, feed conversion efficiency, and mortality.[27–29] Studies that have assessed the economic effects of removing GPAs generally used estimates of these variables rather than actual measurements derived from a large controlled study.[30]

To undertake a formal economic analysis of GPA use, we used results from a three-year non-randomized controlled trial performed by Perdue Farms, Inc. to assess the impact of removing GPAs in broiler chicken production.[29] In the original Perdue study, the economic effectiveness of GPA use was not assessed. In this analysis, we considered: (*1*) the cost of feed with GPA additives; (*2*) the amount of feed needed to produce a unit increase in weight, known as the feed conversion ratio (FCR); and (*3*) the change in value of a flock of broiler chickens at harvest as a function of differences in weight gain, mortality, and condemnation rates.

METHODS

All of the data used for this analysis, except for those listed in Table 4, were published by researchers employed by Perdue Farms, Inc., one of the leading poultry producers in the U.S.[29] Though very relevant to the current debate of GPAs, this study has not received much attention and the journal it was published in is not widely accessible. The Perdue study was conducted from October 1998 to September 2001. Data collection took place in two sites, the Delmarva Peninsula and North Carolina, and involved nearly seven million growing broilers and 158 paired control-trial chicken houses. The houses were standard commercial broiler poultry operations, generally 40 feet wide (12.2 m) and either 400 or 500 feet long (122 m or 152 m). The density of the broilers was similar for both trial and control houses, ranging from 0.73–0.77 square feet (0.222–0.235 m^2) per bird. Most houses had tunnel ventilation and dark-out curtains. Every paired control-trial house on each farm was similar in the number of chickens it received, type and size of building, temperature and lighting schedules, and feeding, watering, and ventilating equipment. The average age at harvest in the two study areas was 52 days.

On the Delmarva Peninsula, 13 farms participated with an average of 9.23 consecutive repetitions of paired control-trial houses on the same farm. In North Carolina, there were six farms with an average of 6.17 consecutive repetitions of paired control-trial houses on the same farm.

Both the control and trial houses received the same coccidiostat program. Only the control houses received GPAs in the starter, grower, and withdrawal feeds. This mix included bacitracin methylene disalicylate, zinc bacitracin, flavomycin, and virginiamycin (amounts not provided). It is assumed that the drugs and dosages used in this study are representative of standard practice in the U.S. broiler chicken industry as a whole (see Figure). The feed was corn-soy based and nutritionally balanced for the Perdue breed.

Inter-trial differences in Table 1 were not provided, even after we requested them by telephone, and thus we were not able to calculate variance or confidence

Table 1. Summary of the effects of removing GPAs from broiler feed (houses without GPAs minus houses with GPAs)

Delmarva Peninsula					
Set of 10 trials	*Mortality rate (percent difference)*	*Difference in avg. weight gain (lbs.)*	*Difference in feed conversion ratio (FCR)*	*Adjusted FCR*	*Total condemnations (percent)*
1 (10/8/98–2/17/99)	0.3	0.01	0.001	0.001	–0.42
2 (12/30/98–5/14/99)	–0.l	0.02	0.012	0.010	–0.14
3 (4/1/99–8/17/99)	0.5	–0.01	0.007	0.007	0.15
4 (7/1/99–12/6/99)	0.1	0.03	0.006	0.003	0.04
5 (10/21/99–2/14/00)	–0.1	–0.06	0.011	0.017	0.13
6 (1/3/00–4/21/00)	0.1	–0.07	0.024	0.030	0.01
7 (3/14/00–7/5/00)	–0.2	–0.04	0.038	0.042	0.31
8 (5/23/00–9/13/00)	0.3	–0.10	0.032	0.041	–0.15
9 (8/1/00–12/7/00)	0.1	–0.06	0.024	0.030	0.44
10 (10/23/00–2/21/01)	0.3	0.07	0.005	–0.002	0.15
11 (1/4/01–5/29/01)	–0.3	–0.07	0.021	0.028	0.08
12 (4/16/01–9/6/01)	0.2	–0.09	0.013	0.023	–0.20
Cumulative average of 120 trials	0.2	–0.03	0.016	0.019	0.03
North Carolina					
Set of 4 trials	*Mortality rate (percent difference)*	*Difference in avg. weight gain (lbs.)*	*Difference in feed conversion ratio (FCR)*	*Adjusted FCR*	*Total[a] condemnations (percent)*
1 (10/8/98–2/17/99)	0.30	–0.10	0.002	0.012	–0.07
2 (12/30/98–5/14/99)	0.00	–0.06	0.017	0.023	–0.13
3 (4/1/99–8/17/99)	0.20	0.00	0.008	0.008	–0.17
4 (7/1/99–12/6/99)[b]	0.10	0.01	0.022	0.021	–0.11
Cumulative average of 37 trials	0.14	–0.04	0.012	0.016	–0.12

NOTE: Positive values for difference in mortality rate, difference in feed conversion ratio, and total condemnations indicate GPAs are effective, while a negative value for difference in average weight gain indicates GPAs are effective.

[a]Data from 31 trials in North Carolina were available for calculating condemnation rates.

[b]Set of seven trials

GPA = growth promoting antibiotics

FCR = feed conversion ratio

intervals. Only average differences along with some best and worst case scenarios are used in the calculations of this study. The analysis also excludes veterinary costs that could change with using GPAs; however, this is unlikely to have been significant given the findings in the Perdue study (see below).

Four essential variables were assessed for each paired control-trial house in the two study areas in order to estimate the economic effects of using GPAs in broiler feed: (*1*) mortality, measured as the percentage of birds dying before being processed; (*2*) average weight, measured as the average weight of the birds from each paired control-trial house before being processed; (*3*) feed conversion ratio (FCR), measured as the average amount of feed in pounds required to produce one pound of weight gain; and (*4*) condemnations, measured as the percentage of birds that were culled at processing due to defects or illness. Feed conversion ratios were adjusted by weight change since feed use efficiency declines as broilers get larger. The adjustment used in the Perdue study is a 0.01 increase in the FCR for every 0.10 pound increase in final weight. Thus, if the average broiler grown with GPAs (control) weighs 0.1 pounds more than the average broiler grown without GPAs (trial), 0.01 must be added to any observed increase in FCR for the trial broiler in order to identify the GPA-related change in FCR. Table 1 provides the results reported in the Perdue study.

Changing to new litter was also addressed by Engster et al. to determine its impact on broiler growth.[29] It is not common practice in the U.S. broiler industry to require cleanout of poultry houses between flocks. Before and after comparisons were made from six paired houses by measuring the difference in weight gain, weight adjusted feed conversion ratios, and mortality of flocks in three flock growing cycles (one growing cycle is equal to the number of days a flock is grown before being processed) before the litter change and three consecutive flock growing cycles after the litter change. The results from changing to new litter are presented in Table 2. In addition, one controlled trial was carried out to assess how GPA use affects weight variability among 250 male broilers and 250 female broilers. Because of limitations on the available data, we used sensitivity analyses to assess a range of scenarios, as the estimated economic impact is highly dependent on small changes in parameter values.

Economic model

The estimated parameters used for the cost analysis came from multiple sources (Table 3). These measures were assumed to be applicable to commercial broiler chicken farms. Costs such as labor, gas, electricity, and water are not included, since these are assumed to be invariant with respect to GPA use and any resulting changes in weight gain, mortality, or condemnations.

(All chicken quantities that follow are per rotation.)

Definitions:

Q_h = number of chicks received by grower

Q_a = number of live broilers accepted by processor

$Q_m = m \times Q_h$ = number of chickens that die before sale (assumed definition)

Table 2. Summary of the before and after effects of changing to new litter[a] (six houses without GPAs minus six houses with GPAs)

Cycle number	*Mortality rate (percent difference)*	*Difference in average weight gain (lbs.)*	*Adjusted difference in FCR*
Delmarva Peninsula			
3rd cycle before	–0.25	–0.007	0.017
2nd cycle before	0.30	–0.010	0.010
1st cycle before	0.01	–0.035	0.019
Litter change			
1st cycle after	–0.50	0.013	0.004
2nd cycle after	–0.41	–0.090	0.014
3rd cycle after	0.15	–0.045	0.036

[a]Values were estimated from histograms and may vary from the original data.

NOTE: Positive values for difference in mortality rate and adjusted difference in feed conversion ratio indicate GPAs are effective, while a negative value for difference in average weight gain indicates GPAs are effective.

GPA = growth promoting antibiotics

FCR = feed conversion ratio

Table 3. Estimates of parameters used for economic analysis

Parameter	*Estimate*
Cost of feed	
Per ton of feed	\$190.00
Per pound of feed	\$0.095
Cost of GPAs	
Per ton of feed	\$1.25–\$3.00
Per pound of feed	\$0.0006–\$0.0015
Payment to growers per lb. of chicken	\$0.0358–\$0.046
Average mortality rate per rotation	5.0%
Average condemnation rate	0.75%
Average feed conversion ratio	1.95
Average market liveweight (lbs./chicken)	5.02

SOURCES: United States Department of Agriculture Economic Research Service [cited 2005 Mar]. Available from: URL: http://www.ers.usda.gov/publications/ldp/xlstables/BTECOST-ALT-MAY.xls

Collignon P. Report on antibiotic use for growth promotion in developing countries. Geneva: World Health Organization; 2004. p. 1-58.

Shane S. Financial impact of removing health-promoting antibiotics from US broiler diets. Poultry Science Annual Meeting; Aug. 11–14, 2002; Newark, NJ.

Center for Agricultural and Natural Resource Policy. Economic situation and prospects for Maryland agriculture. College Park: University of Maryland, 2002. p. 1-94.

Cunningham DL. Cash flow estimates for contract broiler production in Georgia: a 20-year analysis [cited 2005 Mar]. Cooperative Extension Service, The University of Georgia College of Agricultural and Environmental Sciences; 2003. Available from: URL: http://pubs.caes.uga.edu/caespubs/pubcd/B1228.htm

National Chicken Council, Washington; 2004 [cited 2005 Mar]. Available from: URL: http://www.nationalchickencouncil.com/statistics/stat_detail.cfm?id=2

Vukina T. Broilers: enterprise budget for a contract grower [cited 2005 April]. Raleigh: North Carolina State University, Agricultural and Resource Economics; 1993. Available from: URL: http://www2.ncsu.edu/unity/lockers/users/v/vukina/extension/Budgets/broiler1.PDF

$Q_k = k \times (Q_h - Q_m)$ = number living chickens condemned at sale

g = cost of GPAs per pound of feed

w_h = average weight of chicks (lbs./chick)

w_a = average weight of broiler chickens accepted by processors (lbs./broiler)

$f = R \times (w_a - w_h)$ feed requirement/broiler = feed conversion ratio times weight gain from chicks to sale

$C_f = c_f \times f$ = cost of feed/broiler = unit cost times feed requirement

$g^l \times f \leq C_{gpa} \leq g^u \times f$ (lower and upper bounds on cost of GPA per broiler)

$p^l \times w_a \leq P \leq p^u \times w_a$ (lower and upper bounds on payment per broiler)

The lower and upper bounds of costs and payments are derived from different amounts found in the literature on the costs of GPAs and the payments to growers per pound of chicken (Table 3). Note that the latter expression assumes a fixed per-pound payment (not a fixed per-chicken payment). The change in total revenue received by the grower is used to estimate the change in the market value of the unprocessed chickens. (Note that market value is actually significantly greater than grower pay, since the latter reflects only value added by the grower and does not include costs borne by the processor.) Asterisks will denote the modified variables (without GPAs) and all changes are expressed as values with GPA use less values without GPA use.

Mass balance:

$Q_a = Q_h - Q_m - Q_k = (1 - m)\ (1 - k)Q_h$ (with GPAs)

$Q^*_a = (1 - m^*)\ (1 - k^*)Q_h$ (without GPAs)

Two changes are possible when GPAs are withdrawn:

1. The number of chickens sold to the processor may change due to changes in mortality and condemnation rates.
   $Q_a = (1 - m)(1 - k)Q_h$
   $Q^*_a = (1 - m^*)(1 - k^*)Q_h$
2. The payment per chicken may change due to changes in final weight (note that p also has lower and upper bounds, as noted above).
   $P = p \times w_a$
   $P^* = p \times w^*_a$

The change in payment to the grower resulting from ending GPA use is:

Grower payment change/rotation =
$\Delta\text{Value} = P \times Q_a - P^* \times Q^*_a$
$= p \times w_a (1 - m)(1 - k) - p^* \times w^*_a(1 - m^*)$
$(1 - k^*)] \times Q_h$

Incorporating the lower and upper bounds of payments, this gives two forms of this equation:

$\Delta\text{Value}^l = [p^l \times w_a (1 - m)(1 - k) - p^l \times w^*_a(1 - m^*)(1 - k^*)]Q_h$

$\Delta\text{Value}^u = [p^u \times w_a (1 - m)(1 - k) - p^u \times w^*_a(1 - m^*)(1 - k^*)]Q_h$

The change in payment to the grower is taken as a proxy for the change in the payment to producers for the flock. This must be compared to the corresponding change in the cost of the relevant inputs, GPA, and feed. This cost is defined as follows (assuming that mortality occurs just before market):

Change in GPA and feed cost/rotation = ΔCost $= C_{gpa} + (C_f - C^*_f)$

Table 4. Parameter values used for final calculations

Parameter with GPA	*Delmarva Peninsula*	*North Carolina*	
p ($/lb.)	0.0358–0.046	0.0358–0.046	0.0358–0.046
w_a (lbs.)	5.02	4.99	4.98
w_h (lbs.)	0.10	0.10	0.10
m (percent)	5.00	5.20	5.14
k (percent)	0.75	0.78	0.63
g ($/lb. feed)	0.000625–0.0015	0.000625–0.0015	0.000625–0.0015
R (lbs. feed/lb. wt.)	1.95	1.969	1.966
C_f ($/lb. feed)	0.095	0.095	0.095

GPA = growth promoting antibiotics

p = payment to growers per pound of chicken

w_a = average weight of finished broiler

w_h = average weight of chick

m = change in mortality

k = change in condemnations

g = cost of GPAs per lb. of feed

R = average feed conversion ratio

C_f = cost of feed per pound

Since C_{gpa} has lower and upper bounds and since feed cost can be expressed as a function of feed conversion ratio, weight gain, and unit feed cost, this equation can be written as:

$$\Delta \text{Cost}^{l} = \{g^{l} \times R(w_a - w_h) + c_f[R(w_a - w_h) - R^*(w^*_a - w_h)]\}Q_h$$

$$\Delta \text{Cost}^{u} = \{g^{u} \times R(w_a - w_h) + c_f[R(w_a - w_h) - R^*(w^*_a - w_h)]\}Q_h$$

Table 4 shows the parameter values used to evaluate these equations.

RESULTS

Using these parameter values, the following results were obtained for the Delmarva Peninsula data set:

> ΔValue ranges from +0.0014 Q_h to +0.0018 Q_h using lower and upper bounds on price paid per chicken.
>
> ΔCost ranges from +0.0027 Q_h to +0.0111 Q_h using lower and upper bounds on GPA cost.

Based on these data, the use of GPAs increases the market value of the chickens by an amount on the order of $0.0016 per chicken, but increases the growing cost by a larger amount of $0.0069. For the Delmarva Peninsula, withdrawing GPAs from the feed *increases* the net value of the flock by $0.0009 to $0.0097 per chicken.

The same method is used to obtain results for the North Carolina data set:

> ΔValue ranges from +0.0009 Q_h to +0.0012 Q_h using lower and upper bounds on price paid per chicken.
>
> ΔCost ranges from +0.0060 Q_h to +0.0144 Q_h using lower and upper bounds on GPA cost.

In this case, withdrawing GPAs increases the net value of the flock by $0.0048 to $0.0135 per chicken. The two sets of calculations show that, for every combination of assumptions, the removal of GPAs *increases* the net value of the flocks

Perdue's data on the effects of changing to new litter was analyzed using the above formulas. No change in the rate of condemnations was provided; thus, it was assumed that condemnations did not change. For four out of the six cycles, before and after changing to new litter, there was a cost associated with using GPAs (assuming the most conservative estimates of parameters). It was difficult to discern any trends in the data due to the wide variability in the productivity changes across trials.

In a separate analysis of body weight uniformity of 47-day-old male and female broilers that included 1,000 broilers total (250 in each group), Engster et al. found that removing GPAs negatively affected body weight uniformity. Variability, measured by the coefficient of variation (100% × standard deviation/mean), increased by 1.91% for male broilers and 1.16% for female broilers.[29] This variability, however, was not statistically significant, and thus was not included in the economic analysis.

DISCUSSION

This economic analysis is based on the only large data set currently available in the U.S., conducted under conditions of current commercial broiler poultry production. Most studies of GPAs are substantially smaller than this—a few thousand chickens vs. the seven million chickens in this study—and are generally carried out under controlled conditions. The results of this analysis have several limitations. As mentioned above, secondary data were used and inter-trial differences were not available to us, preventing the calculation of confidence intervals. Moreover, assignment of the farms was not randomized, and there may have been some undetected factors that could have affected the results. Variation among sets of trials appears high, but additional information is needed to determine the statistical significance of the productivity changes associated with the use of GPAs. Because of this, we assumed all differences were statistically significant, with the exception noted in the previous paragraph.

No calculation of veterinary costs was included. Based on the information provided in the Perdue study, however, these costs did not appear to change with the removal of GPAs. Interestingly, it appears that mortality rates may be inversely associated with the frequency of litter change, though additional research is required to test this hypothesis. Following the litter change (Table 2), mortality was much lower in the trial group receiving no antibiotics for the first two cycles, though the statistical significance could not be assessed. Furthermore, no cost was attached to the variability in the weight of broiler chickens, which could have a negative impact on profits. More information is needed regarding what added costs would be associated with the reported small increase in variability in weight in order to determine economic effects.

Our study is only of the costs of removing GPAs from poultry production. Thus, we did not consider the potential benefits of GPA removal in terms of medical and public health burdens related to the impacts of increasing risks of antibiotic-resistant infections. This is outside the scope of this study, but germane to an overall policy analysis.

A more intuitive way to understand the findings of our analysis is to recognize that the use of GPAs has three major impacts: (*1*) the cost of feed is increased because of the GPAs; (*2*) the cost of feed is reduced because of the improved feed conversion ratio; and (*3*) the ultimate value of a given flock of chicks is changed due to differences in weight gain, mortality, and condemnation rates. In one of the cases calculated here, the per-chicken value of each change was +0.0144, –$0.0033, and –$0.0018, respectively. The processor, therefore pays $0.0111 more for the feed (i.e., $0.0144–$0.0033) per chicken. However, the finished flock is worth more, calculated at $0.0018 per chicken. But this gain is not large enough, by a significant margin, to compensate for the increased cost of GPA-containing feed. The net effect of GPA use is a lost value of $0.0093 per chicken (about 0.45% of total cost). As presented here, the results are normalized on the initial flock size (number of chicks). Normalizing on finished flock size (Q_a), or on total weight of the finished flock, produces similar results.

Although there have been some recent statements regarding current practices in the use of non-therapeutic antibiotics, the findings in this analysis have important implications for public health policy. Debate in the U.S. has been limited by lack of data on the economic value of GPA use and some researchers have argued that more economic analyses of productivity gains associated with GPAs are needed.[38] While studies conducted in Denmark by government and industry have reported minimal impacts on the poultry industry of discontinuing GPA use,[28] it has been argued by U.S. industry that the Danish experience may not predict outcomes in the U.S. because of differences in animal husbandry, farm organization, and other aspects of food animal production. Contrary to the long-held belief that a ban against GPAs would raise costs to producers and consumers, these results using a large-scale industry study demonstrate the opposite. GPA-associated gains in feed conversion ratios were insufficient to offset the cost of the biological agents. Based on the industry study and the resulting economic impact, the use of GPAs in U.S. poultry production should be reconsidered.

REFERENCES

1. Phillips I, Casewell M, Cox T, Groot BD, Friis C, Jones R, et al. Does the use of antibiotics in food animals pose a risk to human health? A critical review of the published data. J Antimicrob Chemother 2004;53:28-52.
2. Alliance for the Prudent Use of Antibiotics. The need to improve antimicrobial use in agriculture: ecological and human health consequences. Clin Infect Dis 2002;34(Suppl 3):S71-S144.
3. Smith JA. The future of poultry production in the USA without antibiotics. Poultry International 2002;41:68-9.
4. Casewell M, Friis C, Marco E, McMullin P, Phillips I. The European ban on growth-promoting antibiotics and emerging consequences for human and animal health. J Antimicrob Chemother 2003;52:159-61.
5. Libby DA, Schaible PJ. Observations on growth responses to antibiotics and arsonic acids in poultry feeds. Science 1955;121:733-4.
6. Stokstad ELR, Jukes TH. Studies of the growth-promoting effect of antibiotics in chicks on a purified diet. Antibiotics Annual 1958-1959;6:998-1002.
7. Waibel PE, Abbott OJ, Baumann CA, Bird HR. Disappearance of the growth response of chicks to antibiotics in an "old" environment. Poultry Sci 1954;33:1141.
8. Moore PR, Evenson A, Luckey TD, McCoy E, Elvehjem CA, Hart EB.

Use of sulfasuxidine, streptothricin, and streptomycin in nutritional studies with the chick. J Biolog Chem 1946;165: 437-41.
9. Jacobs RL, Elam JF, Anderson GW, Gee LL, Fowler J, Couch JR. Further evidence as to the possible mechanism involved in the growth-promoting responses obtained from antibiotics. J Nutr 1953;51:507-13.
10. National Research Council. The use of drugs in food animals: benefits and risks. Washington: National Academy Press; 1999.
11. Feighner SD, Dashkevicz MP. Subtherapeutic levels of antibiotics in poultry feeds and their effects on weight gain, feed efficiency, and bacterial cholyltaurine hydrolase activity. Appl Environ Microbiol 1987;53:331-6.
12. Woodward SA, Harms RH, Miles RD, Janky DM, Ruiz N. Influence of Virginiamycin on yield of broilers fed four levels of energy. Poult Sci 1988;67:1222-4.
13. Leeson S. Growth and carcass characteristics of broiler chickens fed virginiamycin. Nutr Rep Int 1984;29:1383-9.
14. Izat AL, Colberg M, Reiber A, Adams MH, Skinner JT, Cabel MC, et al. Effects of different antibiotics on performance, processing characteristics, and parts yield of broiler chickens. Poult Sci 1989;69:1787-91.
15. Roth-Maier DA, Kirchgessner M. Nutritional-physiological effects of the antibiotic avoparcin lauryl sulphate in broilers. Arch Geflugelkd 1976;40:60-3.
16. Basheer K, Haleem MA, Mohiyudden S, Seshardri SJ. Effect of aureomycin and terramycin on the live performance, processing losses and meat yeild in broiler birds. Mysore J Agric Sci 1977; 11:229-35.
17. Bougon M, L'Hospitalier R. Effect of efrotomycin on performance and quality of chickens. Bull d'Information. Ploufragan, France: Station Experimental d'Aviculture de Ploufragan; 1985.
18. Boyd W. Making meat: science, technology, and American poultry production. Technol Cult 2001;42:631-64.
19. Cohen ML, Tauxe RV. Drug-resistant Salmonella in the United States: an epidemiologic perspective. Science 1986;234:964-9.
20. Feinman SE. The transmission of antibiotic resistant bacteria to people and animals. CRC handbook series in zoonoses: antibiotics, sulfonamides, and public health. Boca Raton: CRC Press; 1979; 151-71.
21. United States Food and Drug Administration. New animal drugs for use in animal feeds [cited 2005 Mar]. 21CFR558.3; 2000. Available from: URL: http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?fr=558.3
22. Mellon M, Benbrook C, Benbrook KL. Hogging it: estimates of antimicrobial abuse in livestock. Cambridge (MA): UCS Publications; 2001.
23. Animal Health Institute. 2002 survey shows decline in antibiotic use in animals [cited 2005 Mar]. Available from: URL: http://www.ahi.org/mediaCenter/pressReleases/surveyShowsDecline.asp
24. Animal Health Institute. External inquiries require understanding of true intent: from antibiotic, welfare, environmental practices. [cited 2005 Mar]. Available from: URL: http://www.ahi.org/mediaCenter/feedstuffsEditorial.asp
25. National Research Council. The use of drugs in food animals: benefits and risks. Washington: National Academy Press; 1999.
26. Heth DA, Bird HR. Growth response of chicks to antibiotics from 1950–1961. Poult Sci 1962;41:755-60.
27. Dafwang II, Bird HR, Sunde ML. Broiler chick growth response to antibiotics, 1981–1982. Poult Sci 1984;63:1027-32.
28. Emborg H-D, Ersboll AK, Heuer OE, Wegener HC. The effect of discontinuing the use of antimicrobial growth promoters on the productivity in the Danish broiler production. Prev Vet Med 2001;50:53-70.
29. Engster HM, Marvil D, Stewart-Brown B. The effect of withdrawing growth promoting antibiotics from broiler chickens: a long-term commercial industry study. J App Poult Res 2002;11:431-6.
30. Shane S. Financial impact of removing health-promoting antibiotics from US broiler diets. Poultry Science Annual Meeting; Newark, NJ; 2002.
31. Miller GY, McNamara PE, Singer RS. Stakeholder position paper: economist's perspectives on antibiotic use in animals. Prev Vet Med 2006;73:163-8.